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FORMALIN AND HOT WATER AS PREVENTIVES OF LOOSE SMUT OF WHEAT.

By J. C. Arthur.

The loose smut of wheat is a prevalent source of loss to the farmer. There is a saying that "the more smut, the better the crop," which is a fallacious and misleading observation, based no doubt on the fact that conditions which promote the development of the smut parasite, and therefore in seasons giving a heavy growth of wheat, the smut is likely to be unusually conspicuous. Under such conditions it is not rare for the loss due to smut to be as high as 25 to 50 per cent. of the crop. In spite of this loss the yield of grain may be good, but it would have been just so much the better, if the smut could have been prevented. The prevalence of loose smut in wheat varies greatly from year to year, but very often amounts to 10 per cent. of the crop. The loss is almost certain to be considerably greater than casual observation seems to suggest, on account of the inconspicuousness of wheat heads attacked by it.

In the earlier bulletins[7] on grain smuts issued by this Station, it was recognized that loose smut was more difficult to eradicate from wheat than the stinking smut, but in the absence of definite knowledge the assumption was made that the fungicides used against stinking smut would also serve against loose smut, if carefully applied.

In 1891, Messrs. Kellerman and Swingle[8] made extensive trial of fungicides for loose smut, 54 lots being treated, but without decisive results. The amount of smut in the control lots was, however, small, which added to the uncertainty of the test. Their conclusion was that "no grounds based on actual experiment appear to exist for recommending the treatment of the seed with hot water or any other fungicide." A careful review of their data seems to me to show that some forms of their treatment did reduce the amount of smut, but that none showed indications of proving efficient in removing all smut.

The same year this Station also made experiments with loose smut, and the results are here published for the first time. The

[7] Arthur, Smut of wheat and oats, Bull. Ind. Exper. Sta. No. 28, September, 1889; and Treatment for smut in wheat, same, No. 32, July, 1890.

[8] Bull. Kans. Exper. Sta. No. 22.

seed grain used for the test was saved from crops grown on the Station grounds during 1890. Two varieties were employed, the Original Red and the Ontario Wonder. A careful estimate made in the field by counting two or three thousand stalks[9] gave nearly 12 per cent. of smut for the former and over 24 per cent. for the latter, so that the seed available for the test was sufficiently contaminated with smut to ensure marked results.

The seed was treated by immersing five minutes in water at a temperature of 135 Fahrenheit. It was sown October 22, 1891, the day after treatment, each variety occupying two drills, 66 feet long, with an equal area sown with untreated seed as a control. The wheat of all four lots grew well, passed the winter without injury, and gave a good yield. The amount of smut was estimated the middle of June, 1892, with the result that no perceptible influence of the treatment could be detected. The data are given in table II.

TABLE II.

Hot water treatment for loose smut of wheat in 1891-2.

Variety of wheat.	Number of stalks counted.		Per cent. of smut.	
	Untreated.	Hot water 135° for five minutes	Untreated.	Hot water 135° for five minutes.
Original Red.....	3127	3316	6.	5.6
Ontario Wonder.....	2759	2679	15.75	15.85

The amount of smut showing in the resulting crop, although nowhere near so much as in the previous crop from which the seed was taken, was still sufficiently high to make conspicuous any variation that might be traceable to the treatment. That the two varieties of wheat showed correspondingly less smut in 1891 than in 1890, may have been due to several causes, but judging from a number of incidental observations in connection with other experiments as well as this it was probably due largely to the extra manipulation the seed received in cleaning and treatment, which separated the spores to a greater extent than in the usual handling.

A much more elaborate set of experiments was tried in 1898-9 with the aid of the assistant botanist, Mr. William Stuart, in

[9] For exact data see Bull. Ind. Exper. Sta. No. 32, p. 9.

which both hot water and formalin were used. As formalin had been found efficacious against stinking smut of wheat, it seemed highly probably that a right adjustment of strength and length of treatment would show that it could also be used for loose smut, while it was by no means certain that hot water by some method of application would not yet prove serviceable. The two methods were also combined, the solution of formalin being used both hot and cold. The treatment was made especially severe in order to kill the smut spores if possible, though part of the seed might in consequence also be killed. Formalin (40 per cent. formaldehyde) was used in two strengths, one pound of formalin (9.072 gr., 8.2 cc.) to 50 gallons of water, and one to 25 gallons. Less than a pound of seed was treated in each lot.

In order to be more certain of the exact effect of the treatment upon the vitality of the seed, a laboratory test for germination was made, using 200 seeds of each lot placed in a Geneva germinator. It showed that much of the seed was injured, the degree of injury corresponding very well to that shown by vegetation in the open field, but less pronounced. In the field some of the lots not only came up poorly, but grew feebly, and were much injured during the winter. Further data are given in table III.

TABLE III.

Laboratory and field observations on vitality of seed, 1898-9, treatment being in small lots.

TREATMENT.	Percent germination in the laboratory	Field observation.
Untreated	97	good
Formalin, 2 hrs., strength 1-50, at about 73°	96	good
Formalin, 2 hrs., strength 1-25, at about 73°	90	medium
Formalin, 14 hrs., strength 1-25, at about 73°	42	poor
Formalin, 10 min., strength 1-25, at 135°	34	very poor
Hot water, at 132°, Swingle method*	84	medium
Hot water, 10 min., at 135°	63	poor

*The method designated here as the Swingle method is given in Farmers' Bulletin No. 75 of the U. S. Department of Agriculture, written by Mr. Walter T. Swingle, and consists in soaking the seed four hours in cold water, permitting it to drain four hours, then plunging several times into water at 110° to 120°, and finally immersing five minutes in water at 132° to 133°.

The seed was sown September 26, one week after being treated, by means of a hand drill. One strip of six rows was sown for

each kind of treatment and two strips with untreated seed for controls. The growth was not as vigorous as usual, even from the untreated seed, and the winter weather also proved unfavorable to wheat, so that the stand of wheat in the spring was not good, and on some of the treated areas scarcely a plant remained. Moreover, the amount of loose smut showing in the untreated part of the crop was very small, as it had not been possible to secure seed from heavily smutted fields, as in the earlier experiments. Such results as were obtainable are given in table IV, and they cannot be said to do more than indicate a bare possi-

TABLE IV.

Results of treatment of small lots of wheat for loose smut, 1898-9.

TREATMENT.	Number stalks counted.	Percent of smut.
Untreated	2169	.46
Formalin, 2 hrs., strength 1-50, at about 75°	1140	0
Formalin, 2 hrs., strength 1-25, at about 75°	1057	0
Formalin, 14 hrs., strength 1-25, at about 75°	Too few to estimate	.....
Formalin, 10 min., strength 1-25, at 135°		.....
Hot water, at 132°, Swingle method	1421	0
Hot water, 10 min., at 135°	571	.53

bility of finding a successful method of treatment. No smut is recorded for any of the treated lots, except that with hot water for 10 minutes, which showed even more smut than the untreated lot. As this particular treatment was sufficiently severe to kill one-third of the seed, while it does not appear to have killed the smut spores, doubt is thrown upon the efficiency of the hot water treatment, unless it be assumed that a slower method of application be required, like that recommended by Swingle, which seemed to have killed all smut spores provided any were present, with even less injury to the seed. The four methods of using formalin appear to have been effective, and with two hours immersion at a strength of one pound to 50 gallons of water almost no injury resulted to the germinating qualities of the seed. Altogether, however, the test proved in many ways unsatisfactory and inconclusive.

Another test was made at about the same time, using larger quantities of seed and varying the form of treatment in accordance with information secured from the laboratory study of germination in the last trial as recorded in table III. It was made

a test of formalin, used both hot and cold, with a number of variations in the method of application. Two lots of seed were used; one lot being Michigan Amber, grown upon the Station grounds, and the other an unknown variety grown by a neighboring farmer. In neither instance was the amount of smut especially marked in the field. About 8¾ pounds (4 kilograms) of seed were treated at a time.

With the Michigan Amber wheat a rather strong solution of formalin (one pound of formalin to 25 gallons of water) was used, and the time of immersion reduced to one-half an hour, and the application made both hot and cold. The temperature for the hot solution was 136° when the seed was put in, and this was allowed to drop without hindrance. Immersing the seed caused the temperature to drop at once to 126°, 10 minutes later it was 118°, after 22½ minutes it was 113½°, and at the end of the half hour 113°. Two forms of control were also given a half hour soaking in water. The latter was done to offset the soaking required in using formalin, and was expected to show if the wash-

TABLE V.

Treatment of large lots of wheat for loose smut. 1898-9.

Kind of wheat.	TREATMENT.	Percent germination in the laboratory	Percent smut in crop.
Michigan amber.	Untreated	99	1.78
	Cold water, ½ hr., at 71°	98	1.21
	Formalin, ½ hr., strength 1-25, at 75°	88	1.00
	Formalin, ½ hr., strength 1-25, at 136° falling to 113°	74	1.10
Unknown variety.	Untreated	96	.63
	Formalin, 2 hrs., strength 1-50, at about 75°.	90	.13
	Formalin, 2 hrs., strength 1-50, at 127°, falling to 101°	67	.26

ing and swelling of the seed had any effect in itself upon either the growth of the seed or the action of the smut.

For the other variety of wheat the formalin solution was made twice as weak (one pound of formalin to 50 gallons of water), the time of immersion extended to two hours, and the application made as in the former case both cold and hot. For the hot solu-

tion the temperature dropped when the seed was immersed from 127 to 122°, in 55 minutes it stood at 108½°, and in an hour and a quarter at 105°, in an hour and three-quarters at 101½°, and at the end of the two hours at 101°. Only the customary untreated control was used.

After treatment 200 seeds of each lot were placed in a Geneva germinator. The result, see table V, showed that the formalin treatment in each case injured the germinating qualities of the seed more or less, especially when the hot solutions were used. The seed was sown September 29, three days after treatment, with a two-horse drill set to sow five pecks per acre. The vegetation, as seen five days afterwards, the weather having been especially favorable, was good except where the seed had been treated to hot solutions of formalin, these being only fair. A good fall growth was made, but the winter proved unusually severe, and all of the plats suffered, especially along the south halves, where the soil was less favorable to a vigorous growth, but plats having formalin treatment showed the greatest injury. When the wheat began to ripen by the middle of June the treated plats still showed a difference by being somewhat behind the others. The smut was estimated on June 13, by counting one to two thousand stalks in each plat, the data being given in table V.

About three times as much smut developed in the Michigan Amber as in the other variety, giving figures sufficiently large to establish considerable confidence in the results. What strikes one as especially noticeable is the failure of the formalin, however applied, to eradicate the smut, even where the treatment was severe enough to kill nearly a third of the seed. It is apparent however, that the treatment did reduce the smut, amounting to about 63 per cent. in the extreme case, but that this reduction was to any considerable degree due to the fungicidal action of the formalin or hot water may be doubted. It is to be observed in the first place that the same strength of formalin applied cold gave better results in both instances than when applied hot, and yet it is a well established fact that water at the high temperature here used has no mean fungicidal value. It is also to be observed that seed simply soaked in cold water gave a reduction of 32 per cent. of smut over that unsoaked, and certainly no fungicidal action can be ascribed to cold water.

It is the belief of the writer that this reduction of smut is not due materially to any destruction of the smut spores by the treatment, but chiefly or wholly to the incidental removal of the spores

by the additional manipulation that the treated seed receives. Many of the spores are washed away by the water in which the seeds are immersed, as is readily shown by putting a drop of the solution under the microscope, and many more are removed in the process of drying and other extra handling. It is believed that the reduction of smut obtained by the several forms of treatment may be practically accounted for by assuming that the seed is considerably freed from smut incidentally rather than that the smut is killed by the treatment.

Some attempt was made to ascertain directly what action formalin and hot water had upon the smut spores by treating small quantities of smut after the several methods used for the seed and then testing their viability by placing in a hanging drop in a moist chamber, the examination being made with a microscope. Loose smut gathered the middle of June showed abundant germination. For want of time no further examination was made for three weeks, when it was found that the spores which had in the meantime lain in the laboratory would not germinate readily. Smut brought directly from the field during the second week of July showed but moderate germination. Several forms of treatment were attempted, but owing to the indifferent growth of the control sets, the results are not considered reliable and are omitted. The loss of viability by moderate desiccation is an unexpected phase of the problem, for which no explanation can at present be offered. There is evidently need of a more critical examination into the life history of the smut fungus, in order that we may know how surely proposed remedial treatment is directed against the vulnerable part of its cycle.

Practical Deductions.

A study of the above data leads to a pretty definite conclusion that the loose smut of wheat cannot be removed from a crop by treatment of the seed with formalin or hot water, not even when the treatment is so severe as to kill a third or more of the seed. The statement made by the writer in an earlier bulletin of this Station (No. 77, p. 39) still holds good, even after making studies that were expected to overthrow it, that "at present there is no satisfactory remedy or preventive to be recommended for this kind of smut."

There are indirect methods for getting rid of loose smut in wheat, however, that are clearly worthy of attention. That rec-

ommended by my colleague, Professor Latta[10], should be used when feasible. He advises selection of seed from fields known to be free from smut and sowing on land that has not borne wheat for two or three years. In this connection let it be remembered that the loose smut of oats is wholly distinct from that of wheat, and no transfer of one to the other can take place, so that wheat may follow oats as safely as to follow potatoes or corn. Professor Latta also says that "in all cases it is desirable to thoroughly screen wheat for seed, using a strong blast which will dislodge and blow out at least a portion of the smut germs." This last suggestion seems to me, in view of the facts here recorded, to be worthy of special emphasis. A good use of the fanning mill will certainly lessen the smut in the crop, if any spores are present, and will also remove seeds of noxious weeds and the inferior part of the grain, altogether greatly raising the standard of purity and quality.

[10] Bull. Ind. Exper. Sta. No. 45, p. 61. 1893.